ENERGY CONSERVATION OPPORTUNITIES FOR DOWNTOWN REDEVELOPMENT PROJECTS

The Brantford Case

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ABSTRACT

Energy Conservation Opportunities for Downtown Redevelopment Projects -- The Brantford Case is designed to help engineers, developers and municipal planners evaluate the energy conservation potential of proposed downtown redevelopment projects.

The report deals specifically with preliminary plans for the City of Brantford's revitalization program. Architectural design features of the Brantford project are examined, as are technology options such as heat recovery with thermal storage; cogeneration of electricity; on-site waste incineration; centralized heating and cooling; outdoor parking and energy-efficient street lighting; and central monitoring and control.

The report outlines methods for setting up an energy budget as a design guideline and for comparing the cost effectiveness of various options. A checklist of energy conservation measures is provided.

EXECUTIVE SUMMARY

Over the next 20 years, a number of Ontario cities are expected to undertake downtown revitalization programs. At the same time, rapidly rising energy costs will make it imperative that these projects make the best possible use of energy resources.

This report sets down a method for evaluating downtown redevelopment projects in terms of energy efficiency. It is intended as a guide for engineers, developers, and municipal planners involved in the approval of such projects.

Downtown redevelopment programs that combine retail, office, parking, recreational and housing space offer a wide range of energy conservation opportunities.

This study deals specifically with a preliminary plan for the City of Brantford's redevelopment plan. Although the plan has since changed, the methodology and many of the study's conclusions can be applied to redevelopment projects across the Province.

The importance of establishing a practical but challenging energy budget for any project of this nature was stressed by the consultant. The budget for the Brantford project was set slightly lower than best current design practice, at 335 kilowatt hours per square metre per year.

The preliminary redevelopment plan was found to be an energy conserving design. The annual energy consumption was estimated to be about 50 per cent lower than the average of existing buildings in the nearby area.

A number of architectural and energy use alternatives were evaluated to determine their effect on energy use. Recommended architectural changes included better use of solar energy in the atrium areas of the project.

However, the consultants concluded that while architectural changes can help save energy, the effect of such measures depends on the patterns of energy use in the building. For example, a breakdown of energy use for one section of the project showed that lighting accounted for 56 per cent of the energy use while perimeter heating and cooling accounted for only 20 per cent. Changes to lighting would therefore have a greater impact on total energy consumption than architectural changes to the building.

The study evaluated energy technology alternatives including heat recovery with thermal storage, cogeneration of electricity, on-site waste incineration, and central heating and cooling systems. However, the economics of scale of the Brantford project did not justify these alternatives. All costs and price estimates are those prevailing in 1980.

The report also dealt with alternative means of providing outdoor parking and energy-efficient street lighting, and central monitoring for the project.

This report represents one of a number of initiatives dealing with downtown revitalization projects that have been carried out under the Ontario Ministry of Energy's Conservation and Renewable Energy program.

INTRODUCTION

The City of Brantford is just one of a number of Ontario cities that are planning to redevelop their downtown areas. The City of Toronto recently completed the St. Lawrence redevelopment project, and the City of Sarnia has studied the use of central heating in its downtown core. Over the next 20 years, many more Ontario cities are expected to undertake downtown revitalization programs.

During that time, diminishing fuel reserves and rapidly rising energy costs will make it imperative that new structures be examined critically to provide building envelopes and systems which will not only meet basic user requirements but will also operate for the normal life expectancy of the building without wasting precious energy resources.

Downtown redevelopment programs that combine retail, office, parking, recreational and, as in the case of the St. Lawrence project, housing space, offer a wide range of energy conservation opportunities.

This report sets down a method for evaluating the energy conservation features of downtown redevelopment projects, and is intended as a guide for those involved in the design, approval, and construction of such projects. It is based on a study prepared by Tamblyn, Mitchell and Partners for the Ontario Ministry of Energy and Homestead Projects, developers for the proposed Brantford project when the study was commissioned. The study evaluates a preliminary plan for redevelopment that was submitted by Homestead. Although the plan has since changed, the methodology and many of the study's conclusions can be applied to redevelopment projects across the Province.

The Ministry's objective in undertaking the Brantford study was to determine opportunities and recommend ways to achieve energy savings in the redevelopment phase of the revitalization plan for this city of 73,000 people.

The consultant set down costing methods and design criteria and identified the optimum energy sources, based on unit energy costs (1980), for the project.

An energy budget was set for the project, and then compared with the preliminary plan for the redevelopment project. The study stressed the need for an energy budget for any project, set slightly lower than best current design practice. The overall energy budget for the Brantford project was set at 335 $kWh/m^2/yr$ (30 $kWh/ft^2/yr$). The preliminary design for this project compared very favourably with existing commercial office complexes, with an estimated annual energy savings of approximately 50 per cent.

The consultants examined the energy consumption characteristics of the preliminary redevelopment plan using both manual calculations and the Meriwether Computer Simulation Program. The probable variation in annual energy consumption, due to several alternate architectural and energy use considerations, was determined.

Recommended architectural changes included prudent use of the proposed atrium/office arrangement in both sections of the development in order to make full use of winter solar heating, and changes to a covered promenade in the South Colborne Street section of the project.

The consultants stressed that while architectural considerations can help save energy, the effect of such measures depends on the management of energy use in the building. For example, a breakdown for one floor of the Market Square section of the Brantford project showed that lighting accounted for a far greater portion of the energy use than did perimeter heating and cooling. Therefore, changes to lighting would have more impact than the upgrading of building insulation.

The study found that the economics of scale for the Brantford project did not justify use of heat recovery with thermal storage, cogeneration of electricity, or on-site waste incineration. Separate heating and cooling systems were recommended for the two parts of the project, rather than centralized systems.

A key recommendation was that detailed instrumentation be provided for the project and that energy and power consumption of the project be monitored on a continuing basis.

OBJECTIVES OF REPORT

The contractor's task in carrying out this study was as follows:

1. To determine a preliminary energy budget by building function or use for the proposed development;

2. To estimate daily, seasonal and annual energy and peak load requirements in order to identify opportunities to reduce capital investment required for energy supply;

3. To assess and evaluate, on technical, economic, and environmental grounds, various options available for energy savings, including alternative energy supply, storage and distribution systems for the proposed development as well as any other features that could be included in the design and engineering phase to reduce energy consumption;

4. To identify key variables affecting energy and power consumption, to test the sensitivity of the energy budget for Brantford's downtown plan to these variables and to identify appropriate stages during development for incorporating measures for energy conservation;

5. To develop a set of energy budgets as guidelines for the architectural and engineering design of the revitalization project;

6. To suggest a program for monitoring the energy consumption in the new development after construction;

7. To prepare a report explaining the evaluation and selection of energy options, and illustrating the process of designing the energy-efficient redevelopment plan.

BRANTFORD'S PRELIMINARY REDEVELOPMENT PLAN

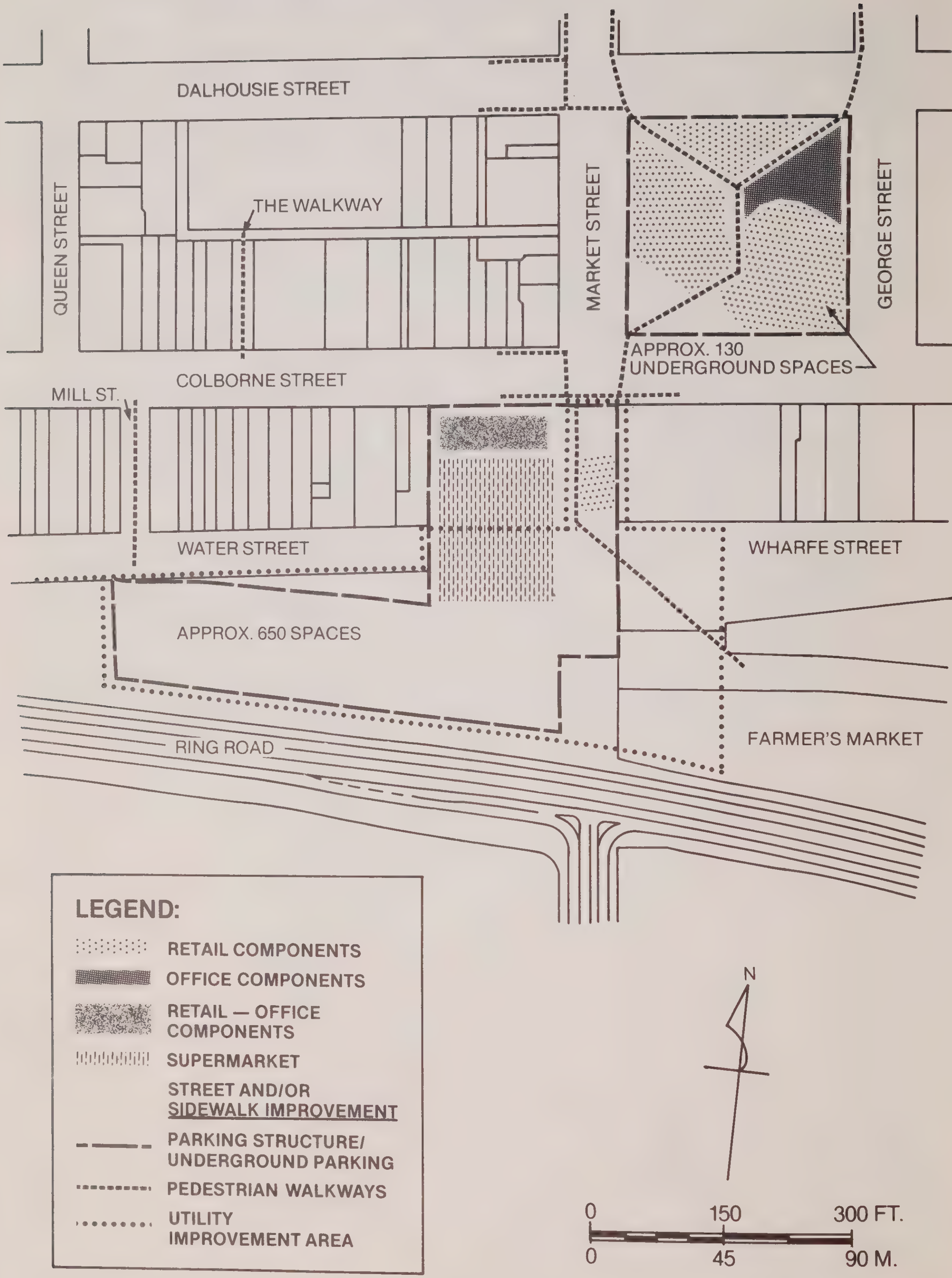
The Brantford redevelopment project as put forward in 1979 in the preliminary plans by Homestead Projects consists of two major areas: the area in the city centre known as Market Square and a second section south of Colborne Street and west of Market Street known as the south of Colborne Street area (see figure 1).

The area south of Colborne Street consists of 25,000 m^2 (265,000 $ft.^2$) of parking facilities to be provided by the City of Brantford, with 5,800 m^2 (62,500 $ft.^2$) of commercial areas to be provided by the developer. An alternate consideration is the addition of two stories of racquet club facilities or offices to the development.

The area known as Market Square consists of a street level parking area with commercial space, a ground floor that is all commercial space, and a second floor to be used for meeting rooms, a library and additional commercial space. A three-storey office building rises above the commercial area. It is co-ordinated into the complex by a three-storey atrium that joins the top storey of the office building to the commercial area. The total area of the Market Square section of the project is approximately 23,000 m^2 (250,000 $ft.^2$).

In all, the development would encompass slightly over 48,000 m^2 (520,000 $ft.^2$).

THE REDEVELOPMENT PLAN



METHODOLOGY USED FOR THE STUDY

Cost effectiveness comparisons

There are several ways of comparing the cost effectiveness of alternate considerations for any given project. These methods include, in ascending order of complexity and accuracy:

1. Simple payback
2. Discounted payback
3. Life cycle costing

All of these methods compare the benefits or savings with the total capital cost of each investment alternative over the life of the system.

Present day value is defined as the amount of money set aside now to pay for the initial cost and the operating cost including all price escalation and interest on the investment.

Simple payback

The simplest method of calculating cost effectiveness is simple payback. Simple payback is the length of time required for accumulated savings to equal the capital investment. For example, an energy saving investment of $10,000 that would lead to annual savings of $2,000 would have a simple payback period of 5.0 years.

However, simple payback does not account for the time value of money, the discount rate, or the escalating cost of energy and maintenance. Furthermore, the savings accrued after all investment costs have been paid back are not credited. Simple payback is applicable only when the discount rate is equal to the fuel price escalation rate, i.e. when the ratio of the escalation rate to the discount rate is 1. Different life expectancies of different equipment cannot be accommodated in simple payback calculations.

Discounted payback

The discounted payback method is better than simple payback because the discount rate, or time value of capital, and price escalation rates of energy can be incorporated.

The actual discount rates usually encountered may vary from 8 per cent to 12 per cent, and the rates of energy price escalation may vary from 7 per cent to 20 per cent depending on the prediction.

The discounted payback period is a function of the ratio, R, of the rate of energy price escalation to the discount rate. Using maximum and minimum figures quoted above:

$$R_{min} = \frac{1 + .07}{1 + .12} = 0.955$$

$$R_{max} = \frac{1 + .20}{1 + .08} = 1.111$$

The maximum error in simple payback period calculations will be less than 12 per cent for the first year under the worst probable combination of discount rate and escalation rate. The error, of course, would be compounded over the life of the period.

For example, using R_{max}, the discounted payback period for the previous example of a $10,000 investment with first year savings of $2,000 is: 3.7 years.

When the payback period is less than five years, simple payback will be accurate within one year, provided that reasonable values for escalation and interest are used. For longer payback periods, it is possible to develop a set of curves which will correct simple payback to discounted payback using the ratio of escalation and discount.

For the purposes of this report, the assumption was made that the escalation rate will be 15 per cent and that the discount rate will be 11 per cent.

$$R = \frac{1 + .15}{1 + .11} = 1.036$$

The 1.04 curve will be used where comparisons are made for alternates where only energy and first costs are the considerations.

The discounted payback method does not account for the savings or benefits accrued after the payback time. Thus, equipment with a lifetime of 20 years and a discounted payback of 8 years would have a period of 12 years of benefits that are not accounted for. See Appendix A for charts to determine discounted or 'exact' payback.

Life cycle costing can address these deficiencies as well as variations in maintenance costs, and is used in appropriate cases in this report. The mathematical calculation for life cycle costing is as follows:

Where variations in maintenance cost and/or life expectancy are involved the calculation will use the expression:

$$C_t = C_i + \sum_{t=1}^{n} C_f \frac{(1+e_f)^t}{(1+d)^t} + \sum_{t=1}^{n} C_m \frac{(1+e_m)^t}{(1+d)^t}$$

Where:

C_t = Total life cycle cost

C_i = Initial capital cost

C_f = First year fuel costs

C_m = First year maintenance costs

e_f = Escalation rate of fuel costs

e_m = Escalation rate of maintenance costs

d = Annual discount rate

n = Life of system in years

By mathematical manipulation Life Cycle Cost can be expressed as:

$$C_t = C_i + C_f \frac{\left[\frac{1+e_f}{1+d}\right]^{n+1} - \frac{1+e_f}{1+d}}{\frac{1+e_f}{1+d} - 1} + C_m \frac{\left[\frac{1+e_m}{1+d}\right]^{n+1} - \frac{1+e_m}{1+d}}{\frac{1+e_m}{1+d} - 1}$$

Design Criteria

Where generally acceptable standards exist, these are used as a basis for the energy calculations. Where standards vary widely, these variations are listed and the effect of the variations is shown in the calculations.

Estimates of the variation in construction costs are outside the scope of this report; however, the recommendation of NRC 16475 "Measures for Energy Conservation in New Buildings" will be effective and should, therefore, be the minimum standards adopted.

Past general commercial practice is also shown to demonstrate the effect of the improved standards.

UNIT ENERGY COSTS

Data have been collected from the local utilities and fuel oil suppliers and the calculations made to demonstrate the effective cost of heating or cooling. These costs were current in 1980.

These calculations show that the optimum fuel for heating and hot water for the project is natural gas. Unit costs for this natural gas are based on an estimated average cost of $2.50/mcf and a seasonal utilization factor of 0.70. This works out to $3.40/M BTU or 1.2 cents/kWh.

Fuel oil prices worked out to $5.77/M BTU or 2.0 cents/kWh for No. 2 light oil, and $4.37/M BTU or 1.5 cents/kWh for No. 6 heavy oil. These calculations were based on the posted price, heat content in BTU's and a seasonal utilization factor of 0.65.

Electric costs for cooling, lighting and power would average approximately 2.5 cents/kWh, based on a monthly average cost of 300 hours use of 3000 kW load.

When electricity is used in a heat recovery refrigeration machine, each kilowatt of electricity will move approximately 3.4 kilowatts of heat from the low temperature to the high temperature side. Therefore, if low grade temperature is available as waste heat, the heat can be re-used at an effective electrical cost of 0.7 cents/kWh ($2.00/M BTU).

Costs for water, sewer and garbage collection and disposal are those for the City of Brantford in 1980.

THE ENERGY BUDGET

Diminishing fuel reserves and rapidly rising energy costs make it imperative that new structures be examined critically to provide building envelopes and systems which not only meet the basic user requirements, but will operate originally and for the normal life expectancy of the building without wasting these precious resources.

Architecture is the art of designing space to serve people and their activities. As the solutions available for any defined use are infinite, it is unrealistic to define any project as the ultimate, or to set exact performance numbers for any project. Each solution offered will have both positive and negative aspects.

A similar array of options is available when designing for the energy use of the project. The engineer can identify areas of energy use for any given project, suggest compromises which will affect the energy use, and design systems which will accommodate the user requirements, using energy in a manner which is optimum for his set of assumptions. However, these assumptions are arrived at by predicting the use patterns of the building and the weather patterns which prevail -- both of which are extremely difficult factors to predict.

Nevertheless, it is possible and desirable to set limits on energy use when such limits do not unreasonably compromise the user requirements. With careful consideration and foresight, cost effective measures can be taken during the design phase to minimize the final energy use. Such cost effective measures will continue to pay handsome premiums as the project ages.

Available documentation on exact use of energy in existing buildings is generally undependable. No standard has been developed for the uniform reporting of energy consumption, and reports which are available lack details of construction, operation equipment and use.

The range of energy consumption rates in commercial buildings is large, as was indicated by a review of data from several reports for buildings in Canada and the northeastern U.S. Ranges of 160 to 1500 $kWh/m^2/yr$ for office buildings and 100 to 1500 $kWh/m^2/yr$ for retail stores were indicated.

Average figures reported vary from 377 to 700 $kWh/m^2/yr$ for office buildings and 366 to 1044 $kWh/m^2/yr$ for retail stores.

Office buildings which are now being designed are predicting energy consumption figures from 150 to 350 $kWh/m^2/yr$ (14 to 33 $kWh/ft^2/yr$).

Some data were available for eight Brantford buildings, however, only partial data were available for six of the eight. Estimates were made for the missing data and annual energy usage for the eight buildings is compared. Much closer agreement is evident from the Brantford summary with ranges of 450 to 860 $kWh/m^2/yr$ with an average of 687 $kWh/m^2/yr$.

If design criteria for new commercial and retail buildings will be set at the low average previously indicated, approximately 366 to 377 $kWh/m^2/yr$, new buildings will operate at approximately 50 per cent of the energy consumption of the average existing buildings.

The study recommends that a preliminary budget for the Brantford redevelopment project be set at 170 $kWh/m^2/yr$ (16 $kWh/ft^2/yr$) for the office section and 500 $kWh/m^2/yr$ (45 $kWh/ft^2/yr$) for retail sections of the project. If these criteria can be met, the overall budget for the project would be 335 $kWh/m^2/yr$ (30 $kWh/ft^2/yr$), a figure consistent with best current design practice.

ARCHITECTURAL DESIGN CONSIDERATIONS

Market Square

Energy consumption for four separate identifiable blocks was estimated for the Market Square project as presently designed: the atrium, the retail floor, the second floor library and meeting rooms, and the three office floors.

Alternatives considered for the Market Square complex included rotation of the building 180°; modification or elimination of the atrium, allowing atrium temperature to swing with outside temperature; increasing glazing or use of reflective double glazing on second floor and office area windows; addition of insulation to walls and roofs; and use of double rather than single glazing for all retail areas.

The base energy total, as well as the energy total from each alternative, was calculated from a separate series of computer program runs using the Meriwether simulation program.

Input data assumptions were obtained for each block along with block floor areas and specific criteria as to system operation, population and hours of use.

Indications are that the project is within the recommended levels of energy budgets proposed and that except for increasing the 2nd floor and office glazing to 50 per cent, double glazing the retail levels, and increasing atrium glass to 100 per cent, the variations had very little effect on the total energy usage.

By allowing the atrium temperature to float up to 35°C, with climatic conditions, the atrium cooling load is reduced. The heating and cooling is not transposed to the adjacent areas and, therefore, there is a 31 1/2 per cent reduction in annual energy use by the atrium and a reduction of 0.5 per cent in energy use for the project. Comfort is not sacrificed because only the unoccupied upper portion of the atrium is affected. This measure is recommended because it involves no capital cost.

The temperature in the upper areas can be reduced by arranging gravity venting of the heat by opening high level vents and allowing the excess ventilation air to move through the area.

Of the other alternatives, serious consideration should be given to the cost effectiveness of improving the wall and roof U factor and to double glazing the windows on the retail levels.

While the variations in architectural details resulted in identifiable differences, it is important to realize that the total energy consumption is not affected to any great extent by architectural design modifications such as orientation and building envelope design.

A breakdown of the energy use for the second floor of the Market Square complex (see Figure 2) shows the reasons for this. Only 20 per cent of the energy consumed on this floor is used to heat and cool the perimeter areas. Increasing the R-value of the walls would thus have only a negligible effect on total energy use. On the other hand, the most significant load is consumed by the lighting which uses 45 per cent of the energy directly. Lighting also adds 60 per cent to the interior cooling load and 40 per cent to the fan energy required. Seven per cent of the total energy consumption is used in delivering the cool air necessary to offset the heat generated by the lighting. In all, 56 per cent of the total energy required by the area can be accounted for as a direct or indirect result of the lighting level. The second floor was simulated at a lighting level of 40 W/m^2. Careful design and use of lighting could reduce the annual consumption attributable to lighting by nearly 50 per cent, or an annual decrease of over 25 per cent in energy for the entire area!

Domestic hot water heating is indicated at 11 per cent of the total energy requirement. This rather high figure results from the design criteria for this space. Significant variation in this percentage will result from actual use data.

Colborne Street Complex

The Colborne Street area of the project consists of a supermarket connected by an atrium type pedestrian mall to one storey commercial space, as well as parking facilities.

The garage design provides for minimum energy consumption by providing maximum use of natural ventilation, daylight and elimination of ventilation where mechanical ventilation is required.

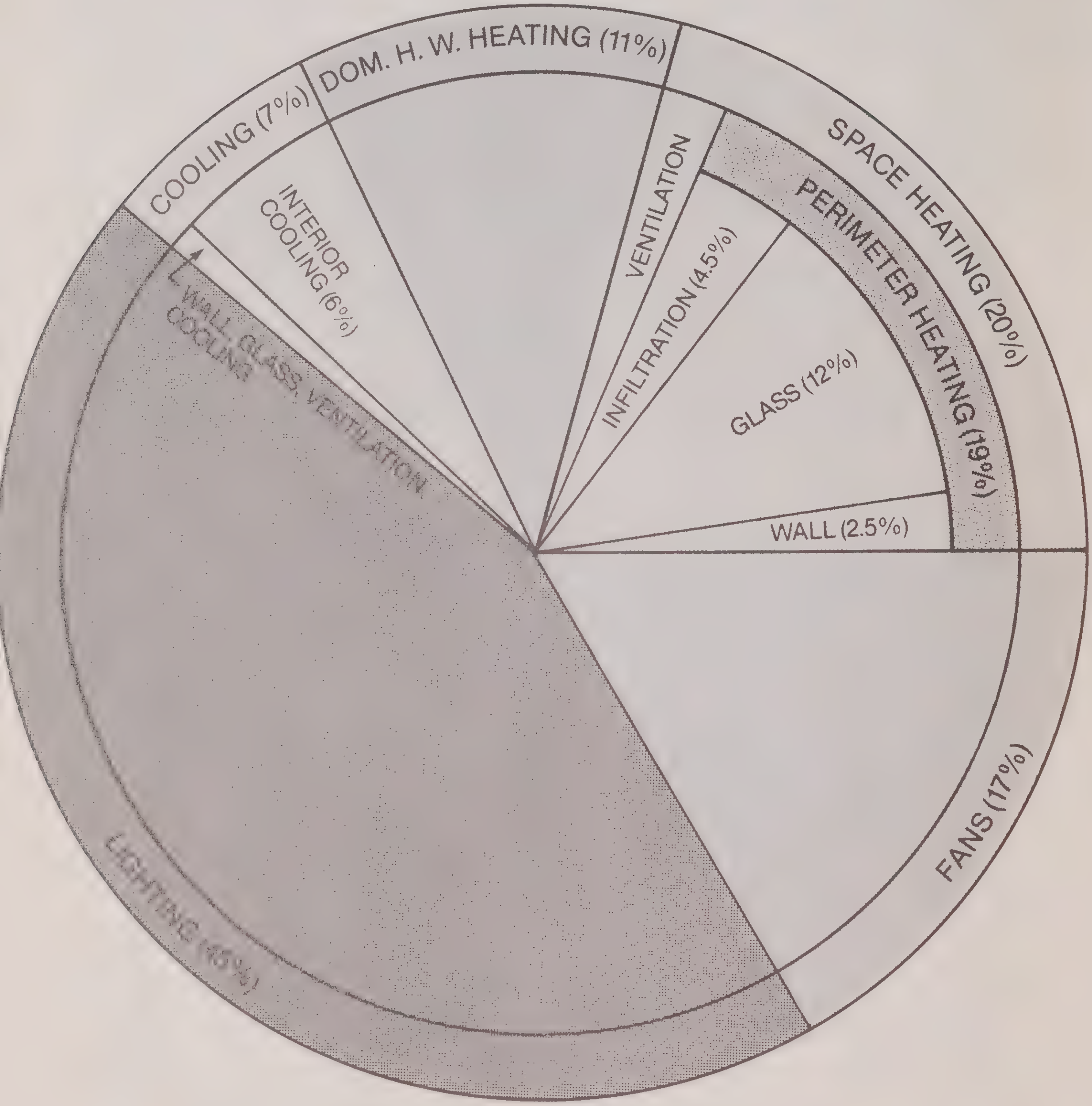
Examination of design criteria for the supermarket indicates a potential savings of 25 per cent in annual heat use by reducing the lighting and by improving the heat recovery of the large refrigeration equipment.

A further 10 per cent is available by increasing the U factors of walls, roofs and slabs to levels recommended by NRC 16574.

While the total energy consumption is less than one third of the Colborne Street total, the atrium and retail area have a very high unit energy consumption level. The high energy use results from the large south-facing windows (covering approximately 50 per cent of the wall areas) which create large cooling and heating loads in the summer and winter months respectively.

ENERGY USE DISTRIBUTION

SECOND FLOOR — MARKET SQUARE



The manual calculations for this block do not account for the effect of the winter sun. However, computer simulations for similar areas indicate that an amount of energy similar to the yearly cooling requirements can be allowed as a credit to the heating. When this credit is allowed the annual use is reduced from 1279 MWh to 931 MWh, a reduction of 28 per cent in annual energy consumption or a reduction from 1076 kWh/m^2/yr to 783 kWh/m^2/yr.

It should be possible to revise the architectural detail of the atrium somewhat to provide summer shade for this glass while allowing winter sun penetration, thus gaining advantages both ways. The retail areas have typical load profiles and no suggestions are made to further reduce the load.

Alternate offices or racquetball courts add a very small increment to the total load due to the stacking of these units and the relatively small glazed areas provided. However, the widely differing use pattern of the two alternates make large differences in the annual cooling, domestic hot water and power requirements. The racquetball facility would use twice as much energy per square metre as the office structure.

ENERGY USE OPPORTUNITIES

Heat Recovery

Studies were made of the cost effectiveness of heat recovery through the use of double bundle centrifugal refrigeration with low temperature heating water. This method involves the use of surplus internal heat to heat the perimeter areas and for ventilation air.

Examination of the heat balance curves for each part of the project, as well as for the total project, indicates that, while the total heat available for the project with heat pump assistance provides adequate heat for the project when occupied, the Colborne Street project in itself is not self-sufficient.

If the total project is considered, it must bear a considerable cost penalty for the interconnection of the two separate sections of the plan. The economics indicate a 20-year payback period.

If heat recovery is considered for the Market Square section of the development only, there would be no interconnecting penalty and the payback period would be 13 years.

Heat recovery is not considered economically attractive because of the long payback period and is, therefore, not recommended.

Thermal Storage

Thermal storage can be achieved by installing suitable reservoirs of material which can be heated at times of surplus heat or cooled with excess cooling capacity. Heat or chilling capacity can be withdrawn at later periods when such surplus can be used. The most economical and suitable arrangement for this type of storage has been found to be concrete tanks holding water.

Thermal storage can save energy by allowing excess heat generated during occupied periods to be used during unoccupied periods. It also provides significant operating cost savings by allowing the selection of smaller refrigeration plants. With thermal storage, the smaller, cheaper plant operates closer to full load for extended periods, reducing demand cost and increasing efficiency.

The analysis for the Brantford redevelopment indicates a payback for the total project of 15 years and a payback of 11.2 years if considered for Market Square only. The use of thermal storage is considered economically marginal and is therefore not recommended.

Centralized versus decentralized heating

The potential for energy or cost savings through centralized heating was examined.

The project size and general commercial practice prescribes the use of normal temperature hot water heating. This heating can be most economically and efficiently provided by the use of incremental atmospheric gas fired equipment. This type of system reduces overfiring and minimizes standby losses, and spare capacity for standby is provided at small cost.

While the cost of standby capacity for a centralized facility is somewhat reduced by consolidating the Colborne Street and Market Street sections of the project, the price structure of the equipment does not offset the costs of providing an interconnecting piping circuit and added pumping costs which result.

It is therefore recommended that separate gas fired atmospheric incremental boilers be provided for space heating and domestic water heating for the project.

Centralized versus decentralized cooling

The redevelopment area can be cooled by separate plants for each project or by one central plant. A central plant with expandable capacity to serve future development, is a further option.

An examination of the alternatives considered lead to a recommendation of the use of separate chillers for the Colborne Street and Market Street projects. The added cost of interconnecting the two projects detracts from the economic advantage offered in less total tonnage required for the central plant.

Cogeneration

Cogeneration is the simultaneous production of heat and electricity for use on site. Systems may be connected to the Hydro grid for backup and for base use, and a standby charge is made for this.

There are two basic types of systems -- one where fuel is burned to produce heat and electricity and the other where waste fuel is burned and the heat and electricity is recaptured.

Where heat is available, waste fuel generator sets can be supplied for $600 to $750 per kW. Waste heat recovery boilers will add $100 to $200 per kW to this cost.

Where fuel is to be burned, systems applicable to commercial projects are usually one of two types: reciprocating engines or gas turbines. A typical steam rate for reciprocating engines or small gas turbines is about 8.0 kg (18 lts)/steam per kW or about 18,000 BTU input per kWh at full load.

Final fuel costs depend on load factor which is the balanced load between heat required and electricity produced.

Both summer cooling and winter heating are highly variable loads. Hot water storage, on the other hand, would provide a significant base heating load.

The Brantford project would involve summer cooling and winter heating, but would not incorporate any significant base heating load. Since high load factor fuel rates will approximate the purchased cost of power, there will be no cost advantage in amortizing the additional capital costs associated with cogeneration.

If an industrial base load could be identified, to which distribution costs would not be prohibitive, cogeneration might be more practical. However, in the case of Brantford, no such load could be identified.

Garbage incineration and heat recovery

A means of reducing energy consumption for a project of this nature would be to use the waste products which are generated in the project to provide part of the heating. The viability of incineration heat recovery has been examined and found to be uneconomical for either major heat production or for peak sharing of heating load for domestic hot water or other identifiable loads which have fairly uniform demands that do not vary widely by season.

For economical waste incineration, a very large uniform load is required to justify the large capital investment in equipment, space and labour. Where waste disposal is an ecological problem, or where disposal costs are unusually high, the credit for these unusual costs can be applied against the cost of heat produced. This would result in lower net costs. In Brantford, waste disposal is very efficiently and economically handled and can be accommodated in a similar fashion for many years to come because low cost landfill sites are available.

The costs of on-site waste disposal do not compare favourably with costs of producing heat from natural gas at the present time.

Further consideration of on-site central waste incineration for heat production for this project is not recommended.

Outdoor parking area and street lighting

In general, parking lots and streets are lit to a recommended level of 10 lux with a 6.1 uniformity ratio for parking lots and 3.1 for street lighting, although recommended street lighting levels may vary considerably, according to use and type of roadway.

This level of light may be supplied by a given lamp of certain wattage, mounted at a given height on poles at given centres. If higher poles are used, the centre-to-centre distance can be increased and the wattage adjusted to create essentially the same light density at ground level.

In general, the energy efficiency of lighting is increased by the use of larger size lighting units mounted on higher poles.

Seven types of light sources mounted at three different pole heights with different spacing were examined for the Brantford project.

Incandescent lighting, while providing excellent colour rendition, results in the highest energy use of all types of light sources usually considered, and does not represent a significant capital cost savings over other more efficient light sources.

Fluorescent fixtures can decrease energy use by 50 to 55 per cent over incandescent, at a capital cost increase of 15 to 30 per cent. However, fluorescent lighting is not commonly used for outdoor lighting in Canada because of the light reduction at low temperature.

Mercury vapour lighting can reduce energy use by an additional 25 per cent. The capital costs are lower than those for fluorescent and only 10 per cent to 20 per cent higher than for incandescent lighting.

Metal halide would reduce energy costs 70 percent over incandescent without appreciable cost penalties.

High pressure sodium can reduce energy use by 85 per cent over incandescent without capital cost penalty.

Low pressure sodium lighting has the lowest use of energy and the lowest life cycle costs. However, low pressure sodium is a monochromatic yellow light which, while excellent for visibility, is generally unacceptable in pedestrian areas because of its colour rendition.

While the study of the Brantford redevelopment project indicates that low pressure sodium lamps mounted on 18 metre poles would require the least amount of energy and would have the lowest life cycle costs, this solution is not recommended due to the colour of the light. However, high pressure sodium lamps on 18 metre poles would provide a reasonably low life cycle cost with good efficiency and acceptable colour rendition.

High pressure sodium is therefore the recommended solution for the majority of standard lighting situations for streets and parking areas. Where special effects are required, different criteria should be applied.

Central monitoring and control

The cost of basic control systems for commercial projects is traditionally about 10 per cent of the total mechanical costs. This figure will depend somewhat on the size of the project, but does not vary significantly for projects over 25,000 square metres. The basic system provided for this cost automatically controls the equipment that presets design set points, but does not provide optimization, automatic starting or stopping or off-normal reporting or alarm.

There is a wide range of controls designed to improve operating and maintenance performance and to reduce operating costs. To keep operating costs to a minimum, it is essential to limit labour input, and at the same time, to provide a high standard of maintenance in order to minimize equipment operating time, to minimize energy waste and to ensure adequate space conditions.

Simple hard wired systems will be most economical where relatively few remote points are required. These systems are relatively inflexible and expensive to modify. Typical costs are $750 to $1,000 per point.

Stage one control processors or central monitoring systems which provide finite capacity for a large group of remote point operations are available for a lump sum of approximately $50,000 plus a cost of $400 to $600 per point. These systems have a large degree of flexibility, and modifications to the points of control can be effected for $100 to $200 per point, by changing of program cards or software.

Stage two control processors, larger more sophisticated computer-oriented systems, have a first cost of about $100,000 and points costs are about $800 to $1,000, including programming. These systems are extremely flexible with programmable capabilities. Most program revisions are made by merely typing in the desired change without adding hardware.

For very large systems, or systems featuring specialized control functions, control response may be effected with direct digital control. This system's approach offers the highest level of control sophistication and the greatest flexibility of program revision, and costs more than the other types of systems.

Thus, the cost of centralization can be anything from a few thousand dollars to in excess of one million, depending on the extent of mechanical systems and degree of sophistication.

The basic control system cost for the Downtown Brantford Redevelopment plan can be expected to cost approximately $200,000. The number of remote control points recommended for this size project may be about 200.

If hard wired, costs of the 200 points would probably vary between $150,000 and $200,000. If a stage one control processor were used, the estimated cost would be approximately $130,000 to $170,000. If a stage two control system were recommended, the probable cost would be about $500,000.

The energy costs for this project will probably exceed $10 per square metre during the base year of operation, or about $300,000. A central control system can provide the facility to avoid at least 10 per cent of this annual cost by proper reporting and control. Therefore, if a five year simple payback is considered economically viable, a control centre cost of at least $150,000 would be justified. This investment would permit the use of a stage one processor type.

It is unlikely that a more sophisticated system would significantly reduce operating costs.

CHECKLIST FOR OTHER OPPORTUNITIES

In the matter of other equipment and systems, the following is a checklist showing recommended measures.

- The use of variable volume air systems wherever practical.
- The use of coffered ceilings with integrated light fixtures where possible, to reduce power input and increase lighting output.
- Minimum air ventilation controlled closely to meet minimum standards.
- Use of thermostatically controlled perimeter heating to match loads closely.
- The use of outside air "free-cooling" either through all-air systems or by use of outdoor air to water heat exchangers to minimize refrigeration.
- The use of enthalpy controllers to use outside air when sufficient cooling is available.
- The use of tempered hot water not in excess of 40°C for domestic water purposes with point of use boosters where higher temperatures are required.
- No garage heating.
- Exterior shading of summer solar exposed glass, where practical, with winter penetration allowed where possible.
- The use of daylight for space illumination when solar load and transmission are properly controlled.
- Use of insulation in air systems and piping in accordance with standards recommended in NRC 16574.
- The use of tenant-provided local recirculation coolers for commercial areas where equipment and operation can be closely matched to load without the required operation of large central equipment to provide cooling for isolated areas. Central equipment should be provided for supply and conditioning of required ventilation air.

INSTRUMENTATION AND MONITORING

Funds should be dedicated at the design stage to properly instrument and monitor the building operating systems. This instrumentation should allow for separate identification and control of significant energy blocks so that use can be identified and monitored.

Provisions should be made for either time-clock operation of systems, or remote control from central station monitors to limit operation times and to record details of use.

Load shedding devices should be considered where identifiable blocks can be allocated priorities and switching provided to automatically shed these loads when conditions permit.

A program of monitoring should be instituted which will continuously monitor the energy use by block loads including lighting, power, heating, and cooling to control the escalation of use and to expose areas of abuse.

No matter how intensive the design for energy conservation, operation which does not minimize operational requirements by proper timing, optimizing temperatures of space and supply, and proper maintenance will result in considerable energy use escalation.

It has been shown in many existing installations that reductions of up to 40 per cent in energy consumption can be made by optimizing use.

CONCLUSIONS AND RECOMMENDATIONS

Diminishing fuel reserves and rapidly rising energy costs make it imperative that new structures be examined critically to provide building envelopes and systems which will not only meet the basic user requirements, but will operate originally and for the normal life expectancy of the building without wasting these precious resources.

As a first step, the consultants recommend that an energy budget be set which is slightly lower than the low average of the existing buildings reported.

The energy budget recommended for the Brantford Redevelopment scheme includes an annual budget of 170 kWh/m^2 (16 kWh/ft^2) for the office section, and 500 kWh/m^2 (45 kWh/ft^2) for the retail section. This will result in an overall budget of 335 $kWh/m^2/yr$ (30 $kWh/ft^2/yr$).

Examination of the costs of providing basic heating and cooling capacity for the project reveals that use of natural gas for heating and electrically driven centrifugal refrigeration will provide the most efficient use of energy at the lowest costs. It is recommended that the project be designed to use these sources of energy.

The consultants also recommended that instrumentation and monitoring be carried out on a continuing basis.

Architectural design opportunities

The consultants pointed out that while the variations in architectural details resulted in identifiable differences, it is important to realize that the total energy consumption is not affected to any great extent by design modifications such as orientation and building envelope design.

For example, a breakdown of the energy use of the 2nd floor section of the Market Square reveals that only 20 per cent of the energy is used to heat and cool the perimeter areas, while lighting directly or indirectly accounts for 56 per cent of the total energy required by the area. Thus, reduction of lighting will have a greater overall effect than architectural changes to the building envelope.

Recommendations related to the Market Square section of the development are as follows:

1. Careful design and use of lighting could reduce the annual consumption attributable to lighting by nearly 50 per cent, or an annual decrease of over 25 per cent for the entire area.

2. While the atrium should be redesigned to provide less exposed summer glass, the use of the atrium in providing passive winter solar heating is important.

3. If the temperature within the upper area of this atrium, above the populated areas, is allowed to vary with outside conditions instead of being cooled, the net effect is to reduce energy consumption of this area by 31 per cent.

The following recommendations relate to the Colborne Street area of the Brantford Redevelopment project:

1. Energy use in the glass atrium of this part of the complex could possibly be reduced by 50 per cent by arranging the glass to provide summer shade and winter solar exposure, by night thermal blanketing, double glazing or by area reduction.

2. No design changes are recommended for the supermarket as its design, according to the preliminary plan incorporated energy conserving features.

3. A conscientious effort in influencing interior designs in the retail areas will result in significant reductions in the predicted annual use in those areas.

4. When considering the alternatives of either additional second storey office space, or the construction of a racquetball facility above the Colborne Street retail area and supermarket, it should be noted that the racquetball facility will use twice as much energy per square metre as the office structure.

Other alternative considerations

1. Heat recovery. Since the project is basically energy conservative, the costs of additional surface area and of double bundle refrigeration equipment to use low level energy, along with the added piping circuits and controls, does not provide an adequate return on investment, and is therefore not recommended.

2. Thermal storage. An examination of the economics of thermal storage for the Brantford Redevelopment project indicates that thermal storage is not economically viable for the project, and is therefore not recommended.

3. Centralized vs. decentralized heating. The energy or cost saving potential of central heating was examined. While the cost of standby capacity for a centralized facility is somewhat reduced by consolidating the Colborne Street and Market Street sections of the project, the price structure of the equipment does not offset the costs of providing an interconnecting piping circuit and resulting added pumping costs. Separate gas fired atmospheric incremental boilers are therefore recommended for space and domestic water heating.

4. Centralized vs. decentralized cooling. The possibility of centralized cooling for the project was rejected in favour of the use of separate chillers for the Colborne Street and Market Street projects. The added cost of interconnecting the two projects detracts from the economic advantage offered in less total tonnage required for the central plant.

5. Cogeneration of electricity. The Brantford project has a widely varying seasonal load and even if provision of cooling from heat activated refrigeration is considered, the loads are insufficient to produce advantageous fuel rates and power rates which can compete with normal rates. Further consideration for on-site cogeneration of power was therefore not recommended.

6. Garbage incineration and heat recovery. Incineration heat recovery was found to be uneconomical for either major heat production or for peak sharing of heating load for domestic hot water or other identifiable loads which have fairly uniform demand not varying widely by season.

7. Outdoor parking area and street lighting. High pressure sodium lighting on 18 metre poles was found to be the most suitable alternative.

8. Central monitoring and control. The system recommended, based on the size and needs for the Brantford project, is a stage one control processor.

APPENDIX A: DISCOUNTED PAYBACK CHARTS

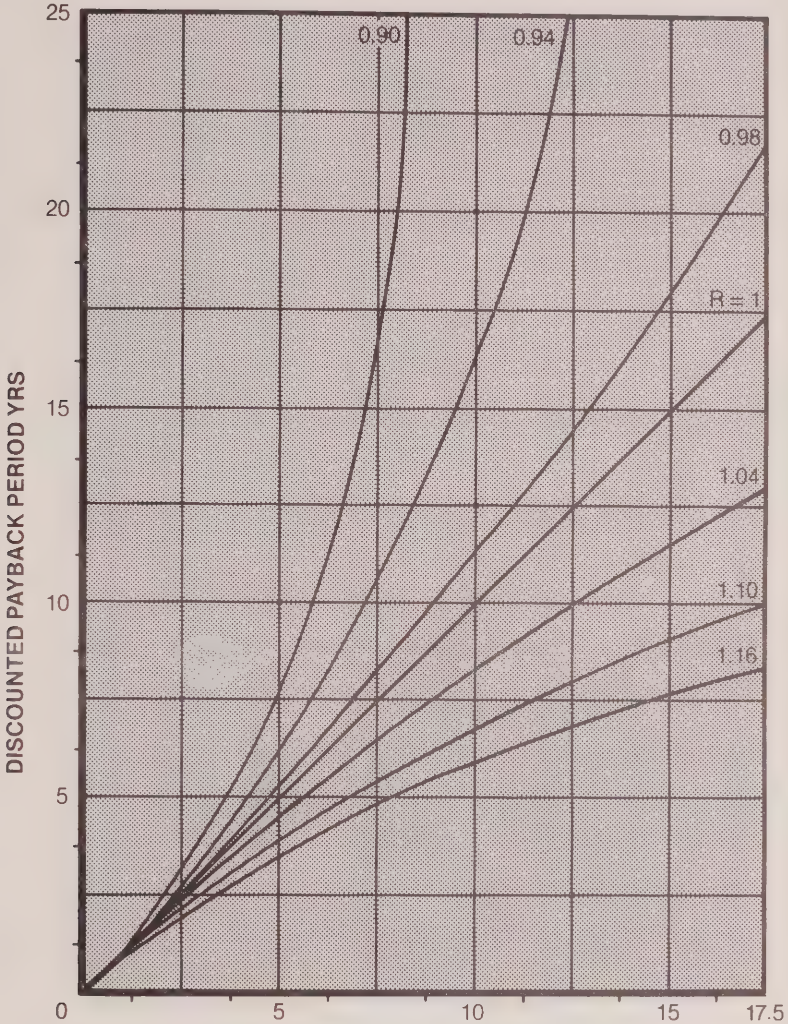


FIG.1: SIMPLE PAYBACK PERIOD YRS

Nomenclature

i = Discount rate as a ratio
e = Escalation rate in energy cost as a ratio

$R = \frac{1 + e}{1 + i}$

n = Number of years
N = Simple Payback Period
S = Reduction in energy cost/year

Present day value of first year's reduction in energy cost

$PDV_1 = \frac{S(1 + e)}{(1 + i)}$; Second year and so on . . .

$$PDV_2 = \frac{S(1 + e)^2}{(1 + i)^2}$$

$$PDV_3 = \frac{S(1 + e)^3}{(1 + i)^3}$$

$$PDV_n = \frac{S(1 + e)^n}{(1 + i)^n}$$

Summing for n years

$$PDV = \frac{S(1 + e)}{(1 + i)} + \frac{S(1 + e)^2}{(1 + i)^2} + \ldots + \frac{S(1 + e)^n}{(1 + i)^n}$$

$$PDV = SR(1 + R + R^2 + R^3 \ldots + R^n) = \frac{SR(R^n - 1)}{(R - 1)}$$

By definition $\frac{PDV}{S} = N =$ Simple Payback Period

$$N = \frac{R(R^n - 1)}{(R - 1)}$$

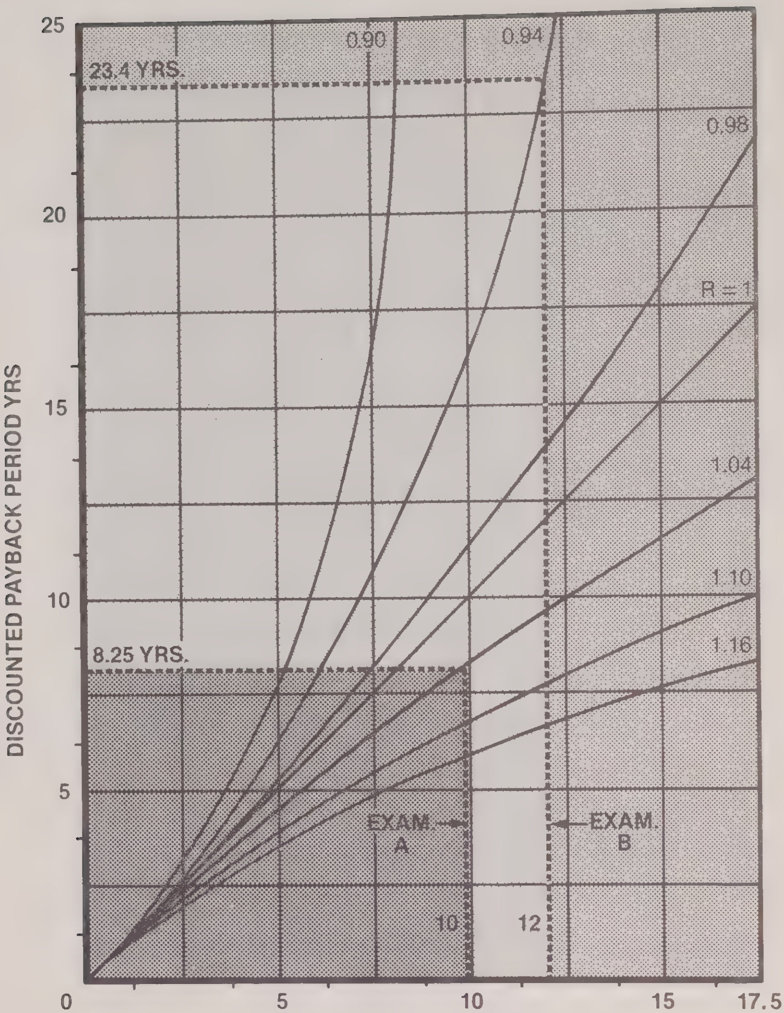


FIG. 2 SIMPLE PAYBACK PERIOD YRS

This simple formula can be programmed into a hand held calculator. This can also be presented as an easy to use chart (see Fig. 1). Note for certain values of R ($R<1$) discounted payback period is infinite for a simple payback period exceeding a certain value. This simply means that discount rates are high compared to savings, resulting in a yearly expense that never pays back the capital.

Example 1

Consider a new retrofit with the following parameters:

Capital required	= $1000
Projected reduction in energy cost	= $100/yr
Projected escalation rate for energy cost	= 12 percent
Discount rate	= 8 per cent

Step 1: Calculate $R = \frac{1.12}{1.08} = 1.04$

Step 2: Calculate simple payback period = $\frac{1000}{100} = 10$

Step 3: As shown in Fig. 2, corresponding to $R = 1.04$ and a simple payback period of 10 years, read exact period of 8.25 years.

Example 2

Consider another retrofit with the following parameters:

Capital required	= $12000
Projected reduction in energy cost	= $1000
Projected escalation rate for energy cost	= 2 percent
Discount rate	= 8 percent

Step 1: Calculate R

$$R = \frac{1.02}{1.08} = 0.94$$

Step 2: Calculate simple payback period $= \frac{12000}{1000} = 12$ years

Step 3: As shown in Fig. 2, corresponding to $R = 0.94$ and 12 year simple payback period, read discounted payback period as 23.4 years.

Note: In this example, if the simple payback period had been 13 years and $R = 0.94$, the discounted payback period would be infinite. In other words, the capital will never be paid back.

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